Japan (East) Sea Dynamics Using Numerical Models With 1/8° to 1/64° Resolution

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Document Number "N0001499WX30057"
http://www7320.nrlssc.navy.miL

LONG-TERM GOALS

Investigate Japan/East Sea circulation dynamics with a hybrid isopycnal/sigma (generalized) coordinate ocean model, and verify numerical results via model-data comparisons.

OBJECTIVES

Investigate Japan/East Sea circulation dynamics in a systematic and progressive fashion using a sequence of increasingly complex ocean models and model-data comparisons. Investigate the impact of upper ocean - topographical coupling and isopycnal outcropping on the mean pathways of the major current systems, including those over the continental shelf region. Also, to assess the impact of different wind forcing on the JES circulation, with emphasis on the branching of the Tsushima Warm Current (TWC).

APPROACH

During the first year an extensive and systematic study of Japan/East Sea dynamics was completed. That study utilized the dynamical modularity and efficiency of the NRL Layered Ocean Model (NLOM), which is mainly isopycnal in design. Sverdrup dynamics were investigated with linear 1.5 layer reduced gravity simulations with wind and/or straits forcing, with realistic geometry and realistic (rather than idealized) wind forcing. The simulations provided a benchmark for simulations which have added some or all of the features like nonlinearity, bottom topography, multiple vertical modes, flow instabilities, isopycnal outcropping, diapycnal mixing, overturning cells in the vertical, thermodynamics, and thermal forcing. The investigation of the mesoscale dynamics is proceeding with the Miami Isopycnal Coordinate Ocean Model (MICOM), which allows the interfaces to intersect the bottom topography, the existence of zero-thickness layers, and includes the shelf circulation.

This will be followed by the development of a hybrid isopycnal/sigma coordinate ocean model (joint with University of Miami) that will have high vertical resolution over the shelf and in the mixed layer everywhere (about 20 isopycnals/levels).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Japan (East) Sea Dynamics Using Numerical Models With 1/8degrees to 1/64degrees Resolution	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Ocean Dynamics and Prediction Branch,Stennis Space Center,MS,39529**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

WORK COMPLETED

MICOM has been set up for the JES region, and several simulations have been completed at 1/8° with 10 isopycnal layers in the vertical. The results are designed to investigate the appropriate values for the physical parameters used in the model and to investigate the role and realism of the thermal forcing functions. Several code modifications have made the original MICOM version more efficient and easier to use. Additional software modules that allow existing NLOM diagnostic programs to be used with MICOM output have also been completed. Lateral boundary conditions have been implemented at the straits to parameterize the throughflow, which is known to have a profound impact on the hydrography in the southern JES (see Preller and Hogan,1999). Atmospheric forcing functions have been extracted and analyzed for the region.

A paper on the effects of eddy variability on the circulation of the Japan/East Sea was published in the Journal of Oceanography. The paper investigated the impact of the momentum flux calculated from satellite altimetry on the geostrophic balance in the Japan/East Sea. The fluxes calculated from the altimetry data were compared to simulated currents calculated with enhanced and suppressed eddy variability. Both show that enhanced mesoscale eddy activity has an impact on the separation latitude of the EKWC. The paper submitted to the Journal of Physical Oceanography last year was reviewed and revised, and is now in press. The paper highlights the importance of horizontal grid resolution, flow instabilities, bottom topography, and isopycnal outcropping for realistically simulating the JES circulation.

Simulated PALACE buoys were seeded and tracked in 1/8° and 1/32° versions of the NLOM (Figure 1). These simulations were conducted at the request of Dr. Steve Riser from the University of Washington to assess possible float trajectories for Dr. Riser's initial PALACE float deployment locations. Two float configurations were analyzed at both resolutions for a period of one year. At each resolution, the profiling nature of the PALACE float (as compared to a buoy that simply remains in the abyssal layer) has a significant impact on the surface trajectory of the float. Additionally, the 1/32° float simulations reveal the impact of the increased nonlinearity and inertial character of the current systems at high horizontal grid resolution. The simulated float trajectories will be compared to the actual PALACE float trajectories.

RESULTS

Although preliminary in nature, the MICOM simulations are all able to realistically reproduce the basic current patterns in the JES. However, similar to the NLOM simulations at the same (relatively coarse) resolution, the MICOM simulations show overshoot of the EKWC from the Korean coast. This problem is somewhat diminished by relaxing to the surface temperature in the mixed layer, and should be further diminished as the horizontal grid resolution is increased. The MICOM simulations realistically depict northward flow over the continental shelf along the coast of Honshu (the Nearshore Branch of the Tsushima Warm Current). The simulations also show realistic seasonal response of the sea surface temperature and mixed layer depth.

From the investigation on the effects of eddy variability, the Reynolds stress due to the geostrophic mesoscale turbulence that is calculated from the altimeter crossover points show that the mesoscale

eddy field increases the cyclonic circulation north of the Polar Front and possibly influences the separation of the EKWC from the Korean peninsula. In addition, the model simulations indicate that the mesoscale field is important in the proper separation of the EKWC at the observed latitude. The model experiments with the eddy field suppressed show the EKWC overshooting the observed separation latitude, and the EKE does not extend far eastward. Only when 1/32 resolution and lower eddy viscosity (afforded by the higher resolution) is used, do the EKE and mean currents appear to be strongly related to the bottom topography.

The journal article now in press (JPO) shows that high horizontal grid resolution, baroclinic instability, bottom topography, and isopycnal outcropping are crucial for realistically simulating the mean circulation and eddy field in the JES. As the horizontal resolution is increased in the simulations, the increasing widespread ability of topographic features to steer upper ocean currents becomes apparent, particularly with respect to the separation latitude of the EKWC. This upper ocean topographic coupling occurs via baroclinic instability and requires that mesoscale eddies be very well resolved in order to maintain sufficient coupling.

IMPLICATIONS

MICOM allows the shelf circulation to be simulated, and allows isopycnals to truly intersect the base of the mixed layer (i.e. layers with zero thickness). This represents an increase in modeling capability for this region, albeit at increased computational costs. However, MICOM simply represents a stepping stone towards development and implementation of a generalized coordinate ocean model (HYCOM). HYCOM will use a sigma-coordinate coordinate system over the shelf region in the mixed layer and an isopycnal coordinate system in the deep water region, thereby retaining the advantages that both coordinate systems offer. The ability to run HYCOM using a higher resolution eddy-resolving grid is crucial, because high resolution is needed to invoke the process by which the surface circulation can be influenced by the abyssal circulation through mesoscale flow instabilities (Hurlburt et al., 1996; Hogan and Hurlburt, 1999). The mechanism by which this occurs, known as upper ocean - topographical coupling, requires that mesoscale variability be very well resolved as well as the presence of realistic bottom topography. In this process, well-resolved eddies are needed to generate strong enough flow instabilities to obtain sufficient coupling. The bottom topography serves to regulate the strength and location of the flow instabilities and steer upper ocean currents. In numerical ocean models, the coupling requires high horizontal grid resolution, at least 1/32° in the JES. Thus the role of upper ocean - topographical coupling is missed in coarser resolution models, which can lead to false conclusions about the role of the bottom topography and unexplained errors in the mean pathways of current systems. The research also addresses the issue of the impact of momentum fluxes on the general circulation. In particular, the effect of the momentum flux on the geostrophic balance indicates that the eddy variability aids in the separation of the EKWC.

TRANSITIONS

NRL has funded 6.2 (ONR) and 6.4 (SPAWAR) projects to develop a 1/16° Pacific nowcast/forecast system north of 20°S using NLOM coupled to a 1/12° Asian marginal seas model using the Princeton Ocean Model. However, the results presented in the submitted journal article suggest that neither of these will have adequate horizontal resolution in the JES. Therefore, the 1/32° JES model based on NLOM could be transitioned as the JES component of this system.

RELATED PROJECTS

Matching funds were provided by 6.1 LINKS in FY99. Participation in ONR JES DRI. Interaction with multinational CREAMS II project.

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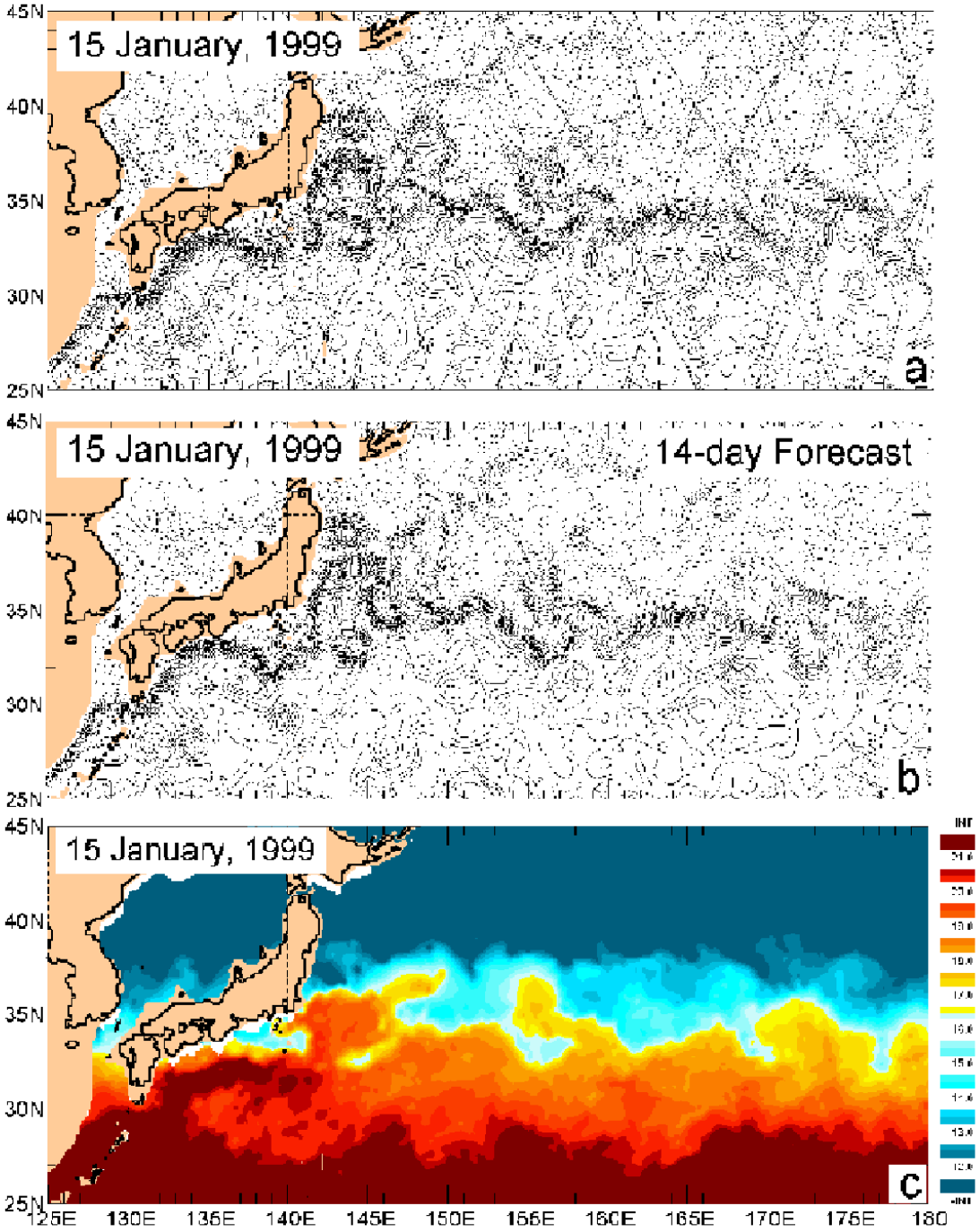

1. Simulated PALACE float trajectories from a 1/8° simulation (a-b) and a 1/32° simulation (c-d). In (a) and (c), the floats are restricted to the abyssal layer. In (b) and (d), the floats simulate the PALACE configuration proposed by Dr. Riser from the University of Washington.